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Exploring the Recent Abundance of Spiny Dogfish in the Gulf of Maine

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Research Article

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—Benjamin Gallo

The Gulf of Maine traditionally has been a popular area for commercial fishing fleets searching for groundfish species. This is particularly true on the continental shelf, an area spanning 200 to 350 miles from the eastern seaboard off the coast of New England to the drop-off of the continental slope (Ames 2004). Decades of overfishing and stock exploitation have led to massive depletions of economically important groundfish biomass in the Gulf of Maine (Ames 2004; Jackson et al. 2001).

In addition to the traditional catches of groundfish species in the Gulf of Maine, commercial fishermen often catch the spiny dogfish (*Squalus acanthias*). Until recently, the spiny dogfish often was marked as "by-catch" and was not a preferred fish species amongst the local commercial fishing fleets. In light of the stock depletion of groundfish such as Atlantic cod *(Gadus morhua)* and haddock *(Melanogrammus aeglefinus)*, the spiny dogfish fishery has grown substantially in the Gulf of Maine. Catch records from 2015 indicated the spiny dogfish as the most harvested commercial finfish (20.7 million pounds) along the entire Atlantic seacoast of the United States (National Marine Fisheries Service 2016).

The author at Rye Harbor, one of New Hampshire's fishing ports.

Recent research also has revealed rising stocks of spiny dogfish in the Gulf of Maine (Carlson et al.2014). Spiny dogfish and traditional groundfish species have similar habitats, and fishermen have been reporting lower catch amounts of Atlantic cod, haddock, and other commercially important groundfish species (Tallack and Mandelman 2009). As has become evident with climate

research, New England is experiencing a dramatic warming period that has begun to have an effect on the ecology of the Gulf of Maine (Harris and Tyrrell 2001). As research continues to indicate the poleward movement of

some groundfish species in response to global climate change (Nye et al. 2009), researchers at the University of New Hampshire (UNH) proposed spiny dogfish are residing in the Gulf of Maine for longer durations each year.

In 2016 I received a Summer Undergraduate Research Fellowship (SURF) to look at spiny dogfish catch from New Hampshire commercial gillnet fishermen in the Gulf of Maine to see if I could draw a relationship between dogfish catch and benthic water temperature. This was in part driven by my longtime interest in fishing. Until recently, my father's family owned a lake house in central Vermont, where we vacationed each summer. I grew to love fishing and the science behind fish behaviors and movements. This love manifested throughout my primary education and led to my eventual pursuit of a bachelor of science specializing in marine, estuarine, and freshwater biology (MEFB) at UNH.

My research on spiny dogfish catch was an extension of a larger, multi-year project begun by my advisor, Dr. Erik Chapman, through New Hampshire Sea Grant, and funded by the Nature Conservancy. The project began in spring 2014 and focused on the time of arrival of dogfish from waters further south. In 2015, the project focused on the time of departure of dogfish in the fall. My SURF grant research focused on the midsummer months (late June to late August) and the movements of the dogfish from the time of arrival to the time of departure.

The conclusions drawn from the multiyear project could (1) help scientists better understand the spiny dogfish ecology and better estimate their population size and (2) help the growing number of commercial fishermen wishing to catch spiny dogfish better locate the species in the hope of improving their catch efficiency. This in turn could help the fishermen avoid depleted, traditional groundfish stocks (cod, haddock, etc.), giving those traditional stocks the opportunity to rebuild.

In recent years, regulations put in place to help these stocks rebuild have made it more costly for fishermen to buy permits to catch haddock and cod. Finding ways to decrease their catch of these traditional, depleted groundfish by going to areas with water temperatures that favor spiny dogfish could prove to be lucrative to the fishermen and support the rebuilding efforts of the groundfish fisheries.

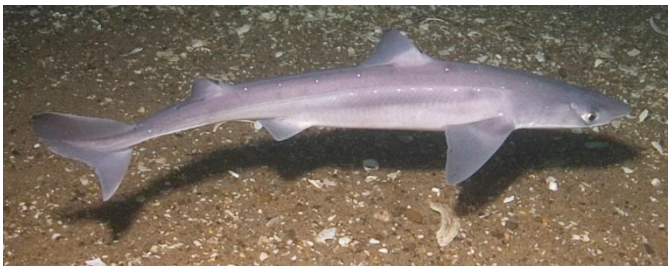

Figure 1. The spiny dogfish (*Squalus acanthias*). *(Photo by Doug Costa, NOAA/SBNMS.)*

Spiny Dogfish Ecology

The spiny dogfish (*Squalus acanthias*) is a small species of shark found in the middle to lower areas of the water column, near the ocean floor. (See Figure 1.) Historically, a small market for spiny dogfish oil existed since the late nineteenth century for use in household lamps (Mcfarland & Beamish 1987). The spiny dogfish

food market did not begin to emerge in earnest until the latter half of the twentieth century, when the more economically profitable cod and haddock populations began to decline. Even still, dogfish is not consumed in quantity in America. Spiny dogfish is almost entirely absent from the American fish consumer diet. Most of the catch is shipped overseas to Europe (NOAA Fisheries Greater Atlantic Region 2017).

Research indicates that spiny dogfish biomass increased from the late 1960s through the late twentieth century (Rago et al. 1998).This trend continues into the twenty-first century, as fishermen continue to report abundant dogfish catches. The mechanism behind this "boom" in dogfish is perplexing to scientists. The spiny dogfish is believed to be a long-lived species (seventeen to seventy years; McFarlane & Beamish 1987) that does not reach sexual maturity until around thirty-five years old (Saunders & McFarlane 1993). Most age/growth models for spiny dogfish have been conducted on the west coast (e.g., British Columbia), and some scientists argue that the age/growth parameters are different on the east coast. Estimates of east coast dogfish indicate sexual maturity around five to seven years of age (Bubley et al. 2011). Given the maturity ages for spiny dogfish, it is imperative to learn about their ecology and movement patterns.

Spiny dogfish are defined as a highly migratory species. Individuals migrate north from Cape Hatteras (North Carolina) to the Gulf of Maine during the summer to feed and then migrate back south during the late fall to winter (NOAA Fisheries Greater Atlantic Region 2017). Ocean temperatures in the Gulf of Maine have been warmer than average for approximately the last ten years (Nye et al.2009), so it was hypothesized jointly by the fishermen and Dr. Chapman that dogfish were migrating earlier, staying longer, and arriving in greater numbers than ever before.

The Three-Phase, Multiyear Project

In order to maximize their catch yields, commercial fishermen have traditionally used water temperature as an important ecological factor to determine the best areas and times to fish (Chapman *unpublished*). In recent years, fishermen have been reporting unusual patterns in fish availability. The unusual patterns present a significant challenge to fishermen to catch their available quotas efficiently (Chapman *unpublished*).

Dr. Chapman's research through the multiyear project attempted to bridge two questions: (1) How are warming water temperatures affecting the fish community in the Gulf of Maine? and (2) Is this water temperature warming possibly related to the recent influx of spiny dogfish over the past ten to fifteen years and the annual decrease of historically important species like Atlantic cod? As part of the federal Sea Grant university partnership, NH Sea Grant focuses on maintaining and promoting sustainable development of New Hampshire's coastal resources through outreach, active research, and education. Dr. Chapman's project was divided into three phases, spanning from June 2014 to November 2016. Phases I and II were supported through grant money provided by the Nature Conservancy to Dr. Chapman and NH Sea Grant. Phase III was supported during the summer of 2016 by my SURF Grant. The Nature Conservancy provided support from late August 2016 until the end of the project in November 2016.

Phase I was completed in the late spring/early summer of 2014 using Visible Assets temperature loggers on one commercial fisherman's boat. Phase II occurred during the late summer 2015 using the same temperature loggers on a different fisherman's boat. The major difference between Phases I and II were seasonal differences in water temperature and daily catch amounts between late spring/early summer and late summer/early fall.

Phases I and II focused on spiny dogfish arrival and departure times only. Phase III sought to determine spiny dogfish movements between these time points as well. Phase III spanned from early June to November 2016 and used HOBOware Tidbit v.2 temperature loggers. My contribution to this project and the information described in this article focused solely on Phase III during the summer fishing months, June to August.

Methods for Phase III

My portion of this research project involved two commercial fishermen and one charter fisherman. One of the commercial fishermen was fishing solely for dogfish, whereas the other commercial fisherman fished a different area and also fished for a separate species: goosefish (*Lophius spp.*), a species of anglerfish that is a delicacy in Asian markets (particularly for its liver; Schmitt 2007). The inclusion of the second commercial fisherman was to provide the unique opportunity to monitor differences in benthic water temperature between two fishing grounds in the Gulf of Maine.

The catch data for my study was recorded by one of the commercial fishermen (Fisherman 1) from their daily catch of spiny dogfish—measured in US pounds. The fisherman reported catch daily to the Yankee Fishermen's Cooperative (Seabrook, NH). I collected this data from the cooperative at the end of the fishing season and stored the data in Microsoft Excel.

The charter fisherman sought various species of groundfish. I included him in the project to determine the nuisance level of spiny dogfish pertaining to his business. Spiny dogfish often travel in large schools (Stoner & Kaimmer 2008), and the customers who pay to charter the boat do not appreciate catching dogfish over cod, pollock, and other traditional groundfish species.

Figure 2. HOBO TidbiT v2 Water Temperature Data Logger size in relation to a hand. *(Photo by Onsetcomp.com.)*

I traveled out on the charter fisherman's boat approximately once per week (June to August) and recorded the daily catches of spiny dogfish. The charter fisherman's client catch data is certainly not indicative of total daily catches as caught by the commercial fishermen, but it provides a framework for dogfish patterns in the fishing areas.

On the two commercial fishermen's boats, I deployed data loggers on separate gillnet strings to collect ocean temperature data. (See Figure 2.) Tags were programmed to measure water temperature every minute and record ocean temperature in increments of 0.1˚C. All tags were located approximately 1.5 m above the lead line (e.g., the bottommost line of the net). I retrieved data from the probes wirelessly between net

deployments and downloaded the data to my computer using U-DTW-1 HOBOware Waterproof Shuttle. As was the case with the charter fisherman, I traveled out with each of the two commercial fishermen approximately once per week (June to August) to wirelessly download the temperature data.

In order to determine benthic water temperature while on the charter boat I used a device called a Castaway CTD. CTD stands for "conductivity, temperature, and depth," but only temperature (˚C) and depth (m) were recorded for the purposes of this project. I attached the CTD to the end of a modified deep-sea fishing rod. During each fishing stop aboard the charter boat, I dropped the CTD to the ocean floor, and then immediately reeled it in. The data I collected from the CTD device was temporarily stored on the CTD device until I connected it to the lab computer and downloaded the data onto Microsoft Excel.

Warming Waters, But Fewer Dogfish?

We had hypothesized that spiny dogfish catches would continue to increase in warming benthic water temperatures. Instead, we found the opposite. Catches declined even while benthic water temperatures rose.

The first commercial fisherman (denoted 1) fished consistently from late June to mid-September, with another week of fishing during the first week of October. His commercial fish catches of spiny dogfish were consistently at the legal trip limits (5,000 lbs per fishing day) from early July to mid-August. From mid-August to the beginning of October, catch amounts declined to approximately 1,000 lbs per fishing day. The water temperatures in the area fished by Fisherman 1 from June to mid-September steadily increased from 5.8˚C to 9+˚C. Therefore, from mid-August to October, there was a steep decline in dogfish catch despite warming water temperatures. The separate week in early October also revealed higher benthic water temperatures (approximately 10˚C) compared to readings collected in September. (See Figure 3.)

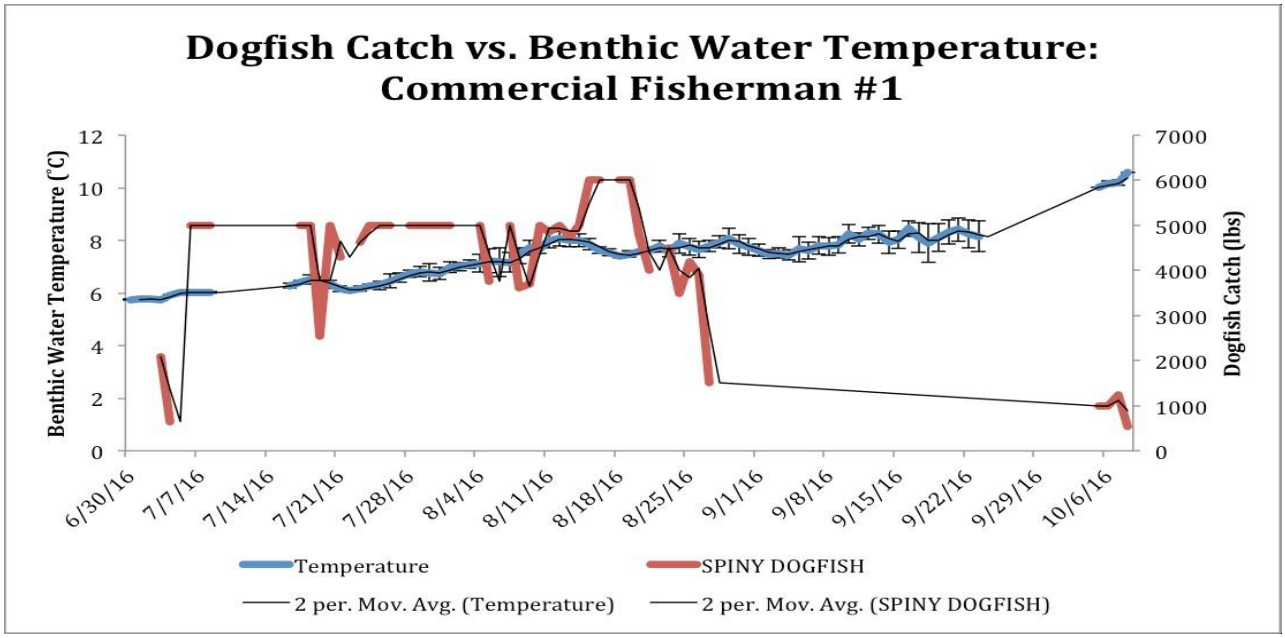

Figure 3. Commercial landings of spiny dogfish collected from Fisherman 1 from June 29 to October 8. Dogfish catch was limited by regulations at 5,000 lbs per fishing day until mid-August, when the limit was increased to 6,000 lbs per fishing day. Water temperature continued to increase into midfall, while dogfish catch markedly decline at the end of August.

The second commercial fisherman (denoted 2) fished consistently from late June to late October. The data collection from late October became sparser, because I was in school and couldn't pick up the Tidbit v2 data loggers at regular intervals. In comparison to Fisherman 1, Fisherman 2 fished further off shore, thus providing the unique opportunity to analyze how offshore water temperature differed in relation to distance from the coastline. Similar to the fishing site for commercial Fisherman 1, the benthic water temperatures where Fisherman 2 fished increased steadily from 5.8˚C to 8˚C from late June to mid-September. In fact, he fished deeper into the fall compared to Fisherman 1, and benthic water temperatures continued to increase steadily into November, with data supporting water temperatures in excess of 10˚C. As previously mentioned, dogfish catch was not formally recorded from Fisherman 2 because he was targeting a different species, goosefish, but rough estimates showed that the occasional bycatch rates remained consistent throughout the fishing season. It is not proper practice to compare catch amounts between fishermen targeting different species, and this is why I did not formally record Fisherman 2's daily dogfish catch. (See Figure 4.)

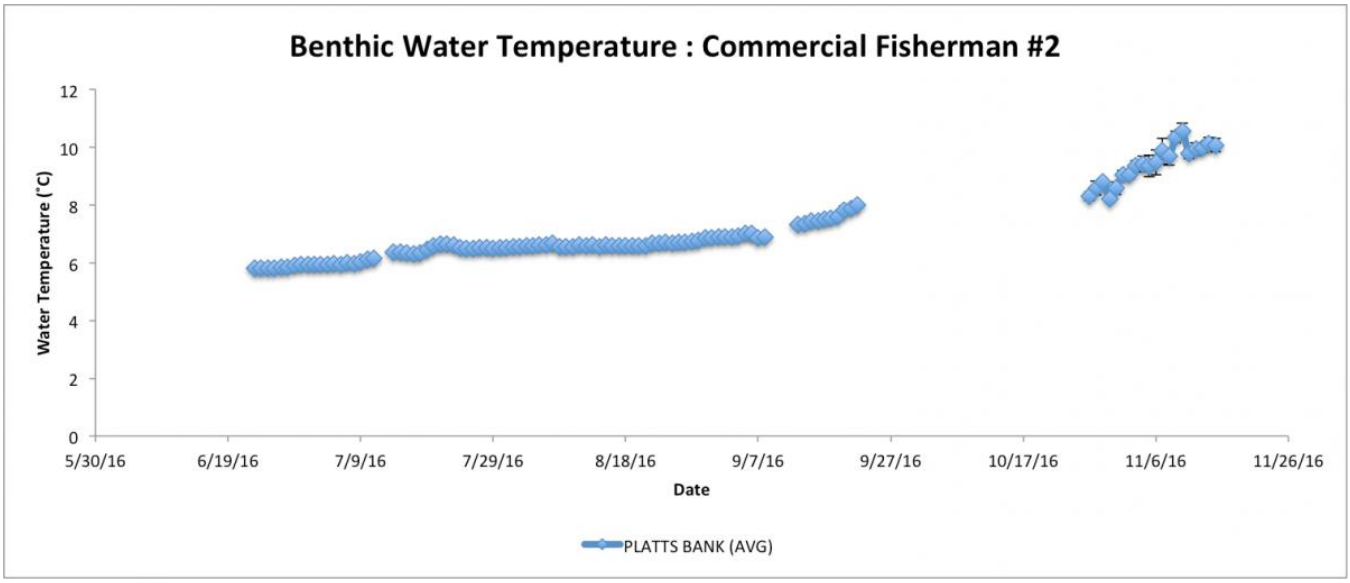

Figure 4. Benthic water temperature (˚C) collected in the waters fished by commercial Fisherman 2. This fisherman's nets were further offshore compared to areas fished by commercial Fisherman 1 and the charter fisherman. Water temperatures warmed more slowly during the summer months (June to August) but water temperatures continued to increase to 10+˚C into November.

The charter fisherman and his clients (denoted Fisherman 3) fished consistently from late June to early September, in approximately the same area as fished by commercial Fisherman 1. In contrast to Fisherman 1, the charter fisherman was actively trying to avoid dogfish, as it is not a preferred species to catch recreationally. The dogfish data I collected was extremely variable. On some trips we didn't catch any dogfish, whereas on other trips we caught many dogfish. The water temperatures I collected over the course of the summer using the Sontek Castaway CTD revealed similar benthic readings when compared to commercial Fisherman 1. Nonetheless, I observed no noticeable pattern in terms of total dogfish catch, unlike the patterns seen on the commercial boats.

Future Research and Takeaways

The critical finding that warmer water temperatures did not lead to higher rates of dogfish catch debunked our initial hypothesis. This finding suggests that factors other than temperature, such as dogfish prey species and water current, are contributing to the movements of spiny dogfish in the Gulf of Maine.

Throughout the course of the summer, it became clear that areas frequented by Fishermen 1 and 3 were very different than the area visited by Fisherman 2. Commercial Fisherman 2 went further offshore, where water temperatures were consistently cooler despite water depth being similar to the areas where 1 and 3 fished. In addition, Fisherman 2's bycatch was consistently smaller and was dominated by male dogfish. Conversely, the areas where Fishermen 1 and 3 fished were dominated by larger, pregnant female dogfish. Interestingly, the gender dominance in the fishing areas of 1 and 3 began to shift toward male dogfish by mid- to late August. This ontogenetic shift remains very perplexing, as not much is known currently about the life history of spiny dogfish and potential breeding and birthing waters in the Gulf of Maine. Any information collecting could go a long way to better managing spiny dogfish to ensure a sustainable fishery for years to come.

From a socioeconomic standpoint, the three-phase project integrated research scientists with fishermen directly tied to the success of the Gulf of Maine fisheries. I worked onboard the aforementioned three fishing vessels throughout the summer, interacting with the fishermen and crew. One of the goals of this project (and of NH Sea Grant) was to extend cooperative research by working alongside fishermen to show them we are all working together to understand marine fisheries and the ocean itself. Fishermen themselves care about sustainability, as they are dependent on fish stocks for their future livelihood. At the beginning of the summer they seemed hesitant to let me help out around the boat, such as helping to clean the gillnets and keeping the deck organized. As the summer progressed, I learned how the crew operated on each boat, and our relationships grew. By the end of the summer, some of them were sad that I wouldn't be around to help them out anymore. I consider this a success in improving researchers' relationships with fishermen through cooperative research.

Some things you can't learn in the classroom, and I learned a lot of those intangibles while completing this project. I gained an appreciation for the commercial fishing industry while also contributing to the sustainability of the resource. This investigation exemplified the fact that things don't always go how you want them to. At first this was quite frustrating. As time progressed, however, I took pride in finding solutions to issues that arose. I feel that problem solving is a very important part of the research process.

Simply put, I don't think I would be prepared for graduate school in fisheries biology if not for the research experience I gained as an undergraduate. This project solidified for me a life goal to pursue a career in research.

I would like to thank the fishermen and crew of the three vessels utilized during this project. A special thanks is also given to the Class of 1959 Fund for Excellence and to Mr. Dana Hamel, the two contributing sources that provided the funds necessary for the SURF portion of this project. This thanks is also extended to the Nature Conservancy for providing funds to all three completed phases of this project. Last but certainly not least, I thank my advisor, Dr. Erik Chapman, and my parents, Chris and Noreen Gallo. Thank you, Dr. Chapman, for providing me the resources and sounding board whenever I needed help. To my parents, thank you for all your moral support on this project and my educational journey.

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Author and Mentor Bios

"If something fails, you can't give up—it just means you have to try harder," says **Ben Gallo**, a marine, estuarine, and freshwater biology major and member of the University of New Hampshire Honors Program from Windham, New Hampshire. While conducting research for his Summer Undergraduate Research Fellowship (SURF), trying harder meant waking up at two or three in the morning to board the boats of the fishermen he worked with. Hard work pays off. Ben gained the respect of the fishermen and became somewhat of an expert on the life history of spiny dogfish. An avid fisherman himself, Ben wants to expand our working knowledge of how to sustain fisheries for future generations. Writing for *Inquiry* has helped Ben work toward becoming a recognized part of the fisheries research community and, in particular, expanding the Seacoast community's knowledge about the local fishing industry. He will continue working toward those goals after graduating in May 2017 by attending graduate school to pursue a master's in fisheries biology. It looks to be a rewarding journey. As Ben says, you see a lot when you're on the water: "Whether it be sharks and whales in the salt or bald eagles and trout on the streams, you never know what you are going to see, and that mystery is what drives me as a scientist."

Erik Chapman is acting director of New Hampshire Sea Grant at the University of New Hampshire (UNH). His research focuses on the influence of environmental variability, including climate change, on marine organisms and ecosystems. He teaches sustainable marine fisheries at Shoals Marine Laboratory; has taught introductory marine biology and ecology in the Department of Biological Sciences; and since 2009 has worked as a fisheries extension specialist for NH Sea Grant and UNH Cooperative Extension. One of his more recent projects has been in collaboration with the Nature Conservancy. This includes the project Ben has been working on, which emerged from listening to fishermen explain how they saw the marine ecosystem changing in response to changes in ocean temperature. Dr. Chapman says it has been incredible to see Ben's skills in scientific inquiry develop over the course of this project. The kind of trust that Ben built with the fishermen is, he says, "priceless in the field of collaborative research." Dr. Chapman is experienced in mentoring undergraduates and is the faculty sponsor for the UNH Sustainable Fisheries and Aquaculture Club, and Ben is his first *Inquiry* author.